29 Nov

MADE EASY

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India's Best Institute for IES, GATE & PSUs

ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-1 : Geo-technical & Foundation Engineering [All Topics]

Environmental Engineering [All Topics]

Name :

Roll No :

Test Centres			Student's Signature
Delhi ☒	Bhopal ☐	Jaipur ☐	
Pune ☐	Kolkata ☐	Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	34
Q.2	50
Q.3	—
Q.4	52
Section-B	
Q.5	46
Q.6	17
Q.7	—
Q.8	—
Total Marks Obtained	199

Signature of Evaluator .... Cross Checked by ....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

(1) Revise Environment subject

(2.) Accuracy is good, slightly increased your presentation.

(3) Practice more and more questions for increasing your attempt.

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Section A : Geo-technical & Foundation Engineering

Q.1 (a) Explain the factors affecting compaction of a given type of soil.

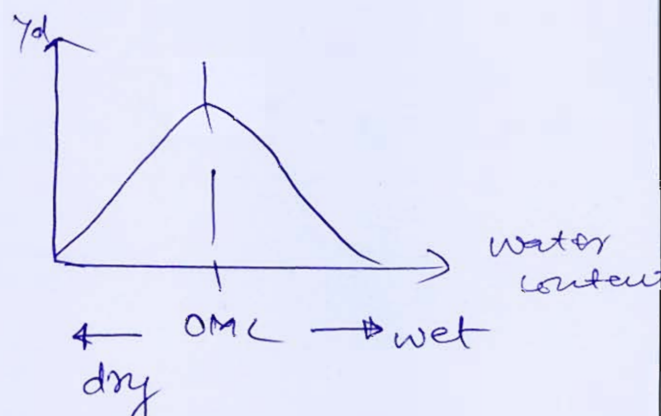
[12 marks]

Solⁿ:

Factor affecting compaction

a) water content.

→ water content when on the dry side the structure of the soil will be flocculent & on the wet side it will be dispersed.



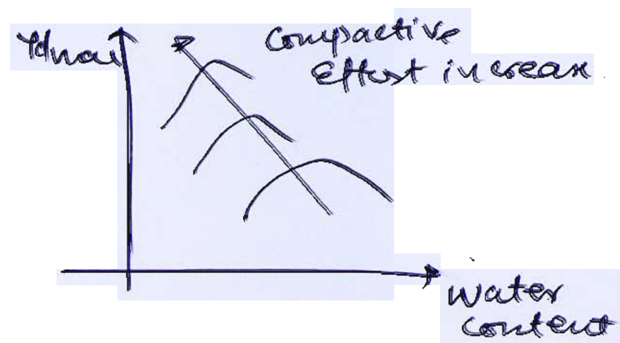
Coeff. of permeability will decrease on the drier side & will increase on the wet side.

Swelling & shrinkage nature will also depend upon water content.

Swelling will be more for the soil on the drier side & shrinkage will be more on the wetter side.

b) compaction effort.

→ when the compactive effort increases, the value of optimum moisture content will decrease & the value of $(\gamma_d)_{max}$ will increase.



(c) Type of compaction

÷ Different types of compacting materials can be used which will affect the compaction.

Materials of compaction

① Sheep foot Rollers
↳ used for clays in the construction of bridges

② Pneumatic Roller
↳ used for all types of soil in Road construction, bridges etc having tampering action.

③ Vibratory Roller
↳ used for sand on the construction site.

④ tamping Rollers.
↳ for all types of soils to tamper the sides of the construction set.

10

Methods

① Standard proctor & Modified procter test

Standard proctor	Modified procter test
Volume of sample = 942 m3	volume = 942 m3
No. of layers = 3	No of layers = 5
No. of blows = 25	No. of blows = 25
Ht of fall = 304 cm (12 inches)	Ht of fall = 410 cm (18 inches)
wt of hammer = 2.49 kg	wt of hammer = 4.8 kg.

②

Light compaction test	Heavy compaction test
Volume of sample = 1000 m3	volume = 1000 m3
No. of layers = 3	No. of layers = 5
No. of blows = 25	No. of blows = 25
Ht of fall = 350 cm	Ht of fall = 450 cm
wt of hammer = 2.5 kg	wt. of hammer = 5 kg.

Q.1 (b) A natural deposit of loose, dry sand, 5 m thick with an in-situ unit weight of 14 kN/m^3 was compacted by vibro floatation technique and the surface settled by 0.5 m. The relative density of the sand after compaction was found to be 85%. If the dry unit weight of sand in the loosest state is 10.8 kN/m^3, then determine:

(i) the unit weight of the soil after vibro-floatation.

(ii) the dry unit weight in the densest state.

(iii) the maximum possible settlement of the surface under ideal compaction.

[12 marks]

Solⁿ:

$(\gamma_d)_{\text{natural}} = 14 \text{ kN/m}^3$ (on site)

$(\gamma_d)_{min} = 10.8 \text{ kN/m}^3$

(i) Relative Density (RD) =
$$\frac{\frac{1}{(\gamma_d)_{min}} - \frac{1}{(\gamma_d)_{\text{(after compaction)}}}}{\left(\frac{1}{\gamma_d}\right)_{min} - \left(\frac{1}{\gamma_d}\right)_{\text{natural}}}$$

$$0.85 = \frac{\frac{1}{10.8} - \frac{1}{\gamma_d}}{\frac{1}{10.8} - \frac{1}{14}}$$

$$\boxed{\gamma_d = 13.4 \text{ kN/m}^2}$$

unit weight of soil after vibro-floatation.

(ii) Dry unit weight weight in its densest state

$(\gamma_d)_{max} \Rightarrow ?$

2

$$RD \Rightarrow \frac{\frac{1}{(\gamma_d)_{min}} - \frac{1}{(\gamma_d)_{\text{after compact}}}}{\left(\frac{1}{\gamma_d}\right)_{min} - \left(\frac{1}{\gamma_d}\right)_{max}}$$

$$0.85 \Rightarrow \frac{\frac{1}{10.8} - \frac{1}{13.4}}{\frac{1}{10.8} - \frac{1}{(\gamma_d)_{max}}}$$

$\gamma_{dmax} \Rightarrow 13.99 \simeq 14 \text{ kN/m}^2$

Q.1 (c) A certain clay layer has a thickness of 5 m. After 1 year, when the clay was 50 percent consolidated, 8 cm of settlement has occurred. For similar clay and loading conditions, how much settlement would occur at the end of 1 year and 4 years respectively, if the thickness of this new layer was 25 m?

[12 marks]

soln:

Assume one-way drainage.

(*) $d = 5\,m$

$$T_v = \frac{C_v t}{d^2}$$

$$C_v \Rightarrow \frac{0.196 d^2}{t} \qquad \left\{ \begin{array}{l} T_v \text{ for } 50\% \\ \text{considation} = 0.196 \end{array} \right\}$$

$$\Rightarrow \frac{0.196 \times 5^2}{1\text{ year}} = 4.9\ m^2/\text{year}$$

(*) $d = 25\,m$ (New layer)

After 1 year:

$$T_v = \frac{C_v t}{d^2} = \frac{4.9 \times 1}{25^2} \Rightarrow 7.84 \times 10^{-3}$$

$$(< 0.283)$$

Hence ~~o/p~~ u will be

$T_v = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$

$100 \times \sqrt{\frac{7.84\times10^{-3}\times 4}{\pi}} = U$

$U = 9.99\%$

(A) ultimate settlement from 1st case.

$U\% = \frac{h}{H} \times 100$

$0.50 \Rightarrow \frac{8}{H} \Rightarrow \boxed{H = 16\text{ cm}}$

(A) Now for 25m soil for 1 year.

$U = \frac{h}{H} \times 100$

$\frac{9.99}{100} \Rightarrow \frac{h}{16}$

$\boxed{h = 1.5984\text{ cm}}$

(A) for 25m soil, 4 years.

$T_v = \frac{4.9 \times 4}{25^2} \Rightarrow 0.03136$

$(< 0.283$

$\frac{\pi}{4}\left(\frac{U}{100}\right)^2 = 0.03136$

$U = 19.98\%$

6

$U = \frac{h}{H} \times 100$

$\frac{19.98}{100} = \frac{h}{16}$

$\boxed{h = 3.197\text{ cm}}$

settlement ~~for 25 m~~

at 1 year = 1.5984 cm

at 4 year = 3.197 cm

Q.1 (d) (i) Determine the area ratios for the following soil samplers and comment on the nature of samples obtained in each of the samplers.

1.	Core cutter	160 mm OD	145 mm ID
2.	Split barrel	50 mm OD	34 mm ID
3.	Seamles tube	55 mm OD	52 mm ID

Here OD is outer diameter and ID is internal diameter of the soil sampler.

(ii) A canal having slopes 1 to 1 is proposed to be constructed in a cohesive soil to a depth of 6 m below ground surface. The soil properties are given below:

$\phi_u = 15°$, $C_u = 18$ kN/m^2, $e = 0.75$, $G_s = 2.65$, $S_n = 0.08$

Find the factor of safety with respect to cohesion against failure of the bank slopes when the canal is full of water.

[6 + 6 = 12 marks]

SST no.

(i) Area Ratios

$$= \frac{OD^2 - ID^2}{ID^2}$$

① core cutter

$$= \frac{160^2 - 145^2}{145^2} = 0.217$$

② Split barrel

$$= \frac{50^2 - 34^2}{34^2} = 1.162$$

5

③ Seamles tube

$$= \frac{55^2 - 52^2}{52^2} = 0.1187$$

Seamles tube is very good in comparison to the core cutter & split barrel.

Because we want the Area Ratio to be small.

So the sample collected from Seamles tube is highly undisturbed.

(ii) $S_n = \frac{c}{\gamma H} = \frac{c}{\gamma (FOS) H_c}$

$$\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w = \left(\frac{2.65 + 0.75}{1+0.75}\right) \times 9.81$$

$\Rightarrow 19.05$ kN/m^2

$$H_c \Rightarrow \frac{4c}{\gamma\sqrt{K_a}} \qquad \left\{ K_a = \frac{1-\sin\phi}{1+\sin\phi} \right\}$$

$$= \frac{1-\sin 15}{1+\sin 15} \Rightarrow 0.5888$$

$$H_c \Rightarrow \frac{4 \times 18}{19.05\sqrt{0.5888}}$$

$$\boxed{H_c \Rightarrow 4.925\,m}$$

$$S_n = \frac{c}{\gamma(FOS)H_C} = \frac{18}{19.05 \times FOS \times 4.925}$$

1

$$0.08 = \frac{18}{19.05 \times FOS \times 4.925}$$

$$\boxed{FOS = 2.398}$$

Q.1 (e) What are the principal modes of soil failure based on the pattern of shearing zones? Explain with neat sketches along with load settlement curve of each of the modes.

[12 marks]

Soln.

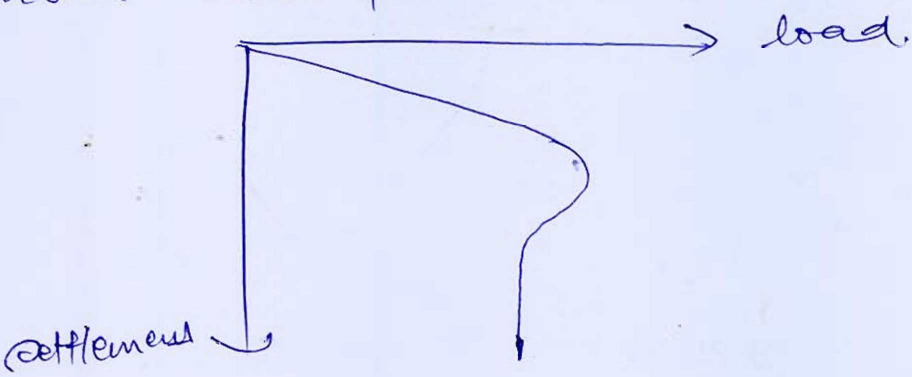
Principal mode of soil failure

(1) General shear failure.

→ In dense & shallow foundation.

→ the soil below the foundation forms a wedge underneath it then the soil pressure Extends upto the ground surface & heaving of soil takes place in General shear failure.

→



→ their is a clear cut failure point in general shear failure.

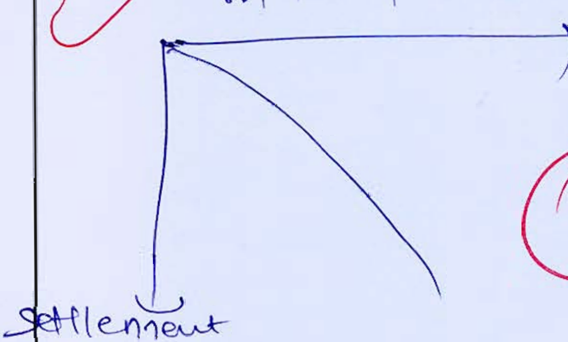
(ii) local shear failure.

→ In loose sand, deep & shallow depth foundation

→ No clear - cut failure point

→ have to take the log curve to determine the failure point

→ slight unheaval upto the surface of the pressure distribution.

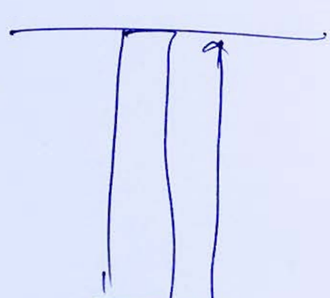


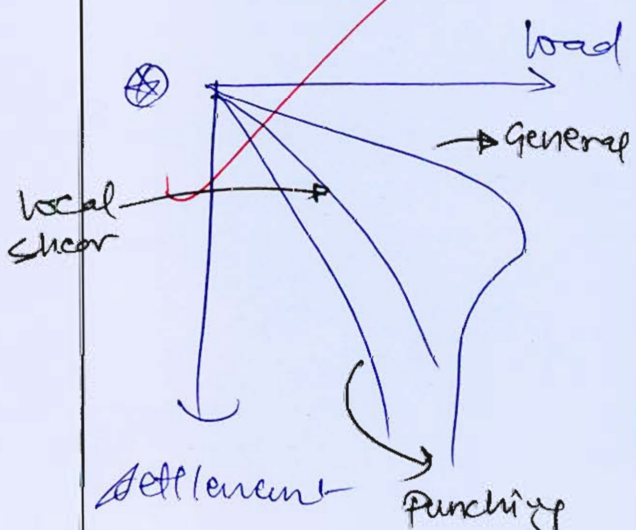
(iii) ~~Log~~ punching shear

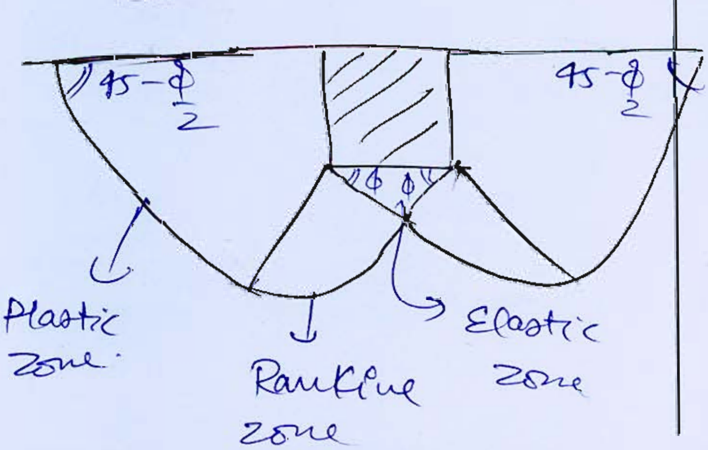
→ In deep foundation, loose or dense sand

→ No unheaval

→ No stress distribution upto the surface







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Q.2 (a) (i) The results obtained from a series of $\overline{CU}$ tests on a soil are as below:

$C_{cu} = C'_{cu} = 0$

$\phi_{cu} = 20°, \phi'_{cu} = 45°$

A sample of this soil was tested in a $\overline{CU}$ test under a cell pressure of 120 kN/m^2.

Determine

1. Deviator stress at failure.
2. Pore water pressure at failure
3. Minor principal effective stress at failure
4. Major principal effective stress at failure

(ii) Mention the advantages and limitations of triaxial test.

[16 + 4 = 20 marks]

Soln:

(i) CU test (Total stress parameter)

$\sigma_3 = 120 \ KN/m^2$

(1) At failure

$\sigma_1 = \sigma_3 \tan^2(45 + \frac{\phi}{2}) + 2c \tan(45 + \frac{\phi}{2})$

$\sigma_1 \Rightarrow 120 \tan^2(45 + \frac{20}{2}) + 0$

$\sigma_d + 120 = 120 \tan^2(45 + \frac{20}{2})$

$\boxed{\sigma_d = 124.75 \ KN/m^2}$

↳ deviator Stress

$\boxed{\sigma_1 \Rightarrow 244.75 \ KN/m^2}$

(2) At failure

(take Eff. stress parameter)

$\bar{\sigma}_1 = \bar{\sigma}_3 \tan^2(45 + \frac{\phi'}{2})$

$\bar{\sigma}_1 \Rightarrow (120 - u)\tan^2(45 + \frac{45}{2})$

$(244.75 - u) = (120 - u) \times 5.828$

$244.75 - u \Rightarrow 699.41 - 5.828u$

$\boxed{u = 94.17 \ KN/m^2}$

↳ Pore water Pressure.

(3) Minor principal Eff. stress at failure

$\bar{\sigma}_3 = \sigma_3 - u$

16

$\Rightarrow 120 - 94.17$

$\Rightarrow 25.83$

(4) Major-principal Eff. stress at failure

$\bar{\sigma}_1 = \sigma_1 - u$

$\bar{\sigma}_1 = 244.75 - 94.17$

$\boxed{\bar{\sigma}_1 = 150.58}$

(iii) Advantages of triaxial test & disadvantage

→ diff conditions of drainage.
 a) unconsolidated undrained
 b) consolidated drained.
 c) consolidated undrained,

3

→ can be used for both soils

→ failure plane is not predictable

→ to maintain the cell condition is difficult

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Q.2 (b) A retaining wall with a smooth vertical back retains sand backfill for a depth of 8 m. The backfill has a horizontal surface and has the following properties:

$C' = 0, \phi' = 30°; \gamma = 17\,kN/m^3, \gamma_{sat} = 21\,kN/m^3$

Calculate the magnitude of the total thrust against the wall for the conditions given below:

(i) Backfill fully drained but the top of the wall is restrained against yielding.

(ii) Backfill fully drained and the wall is free to yield.

(iii) Wall is free to yield, water table at 4 m depth and there is no drainage.

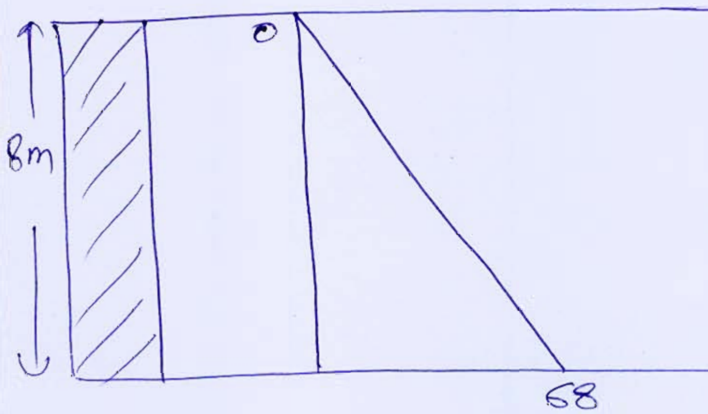
Also, determine the point of application of resultant thrust for case (iii).

[20 marks]

Sol^n:

(i) $K_0 = 1 - \sin\phi = 1 - \sin 30° \Rightarrow 0.5$

$\gamma \Rightarrow 17\ kN/m^3$



① $\sigma_v = \gamma z$

② $\sigma_h = K_0 \gamma z$

$= 0.5 \times 17\, z$

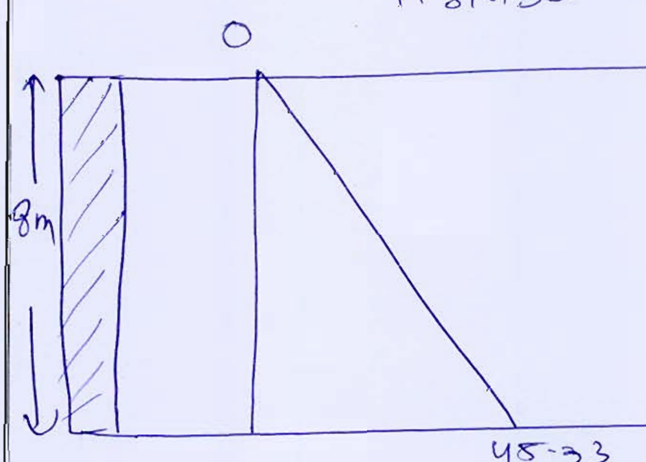
③ at $z = 0$, $\sigma_h \Rightarrow 0$

at $z = 8$, $\sigma_h \Rightarrow 68$

total thrust $\Rightarrow \frac{1}{2} \times 68 \times 8$

$\Rightarrow 272$

(ii) $K_a = \frac{1 - \sin 30}{1 + \sin 30} \Rightarrow \frac{1}{3}$



① $\sigma_v = \gamma z$

② $\sigma_h = K_a \gamma z$

$\Rightarrow \frac{1}{3} \times 17 \times z$

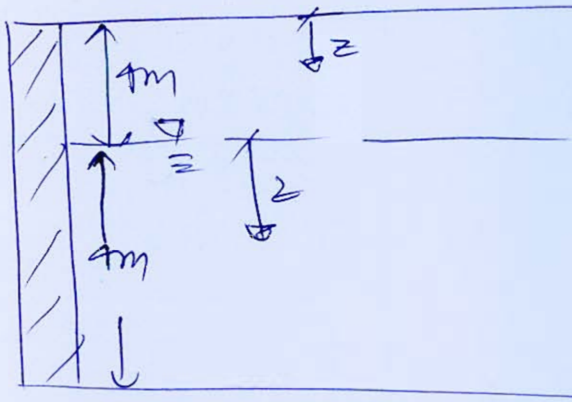
③ at $z = 0$, $\sigma_h = 0$

at $z = 8$, $\sigma_h = 45.33$

total thrust $\Rightarrow \frac{1}{2} \times 8 \times 45.33$

$\Rightarrow 181.32$

(iii) $K_a \Rightarrow \frac{1}{3}$



① $\sigma_v = \gamma z = 17z$

② $\sigma_h = K_a(17z)$

③ at $z=0$, $\sigma_h \Rightarrow 0$, at $z=4$, $\sigma_h = 22.67$

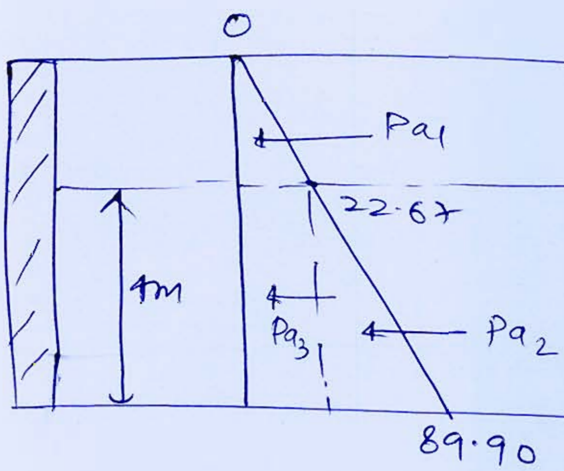
① $\bar{\sigma}_v \Rightarrow 17\times4 + \gamma_{sat} z$

② $\sigma_h = K_a\bar{\sigma}_v + u$

$\Rightarrow \frac{1}{3}(68+21z) + 9.81z$

③ at $z=0$, $\sigma_h = 22.67$

④ at $z=4$, $\sigma_h \Rightarrow 89.90$



15

from base.

$Pa_1 \Rightarrow \frac{1}{2}\times22.67\times4$, at $z_1 \Rightarrow 4+\frac{1}{3}\times4$

$\Rightarrow 45.34$ ✓ $\Rightarrow 5.33$

$Pa_2 \Rightarrow \frac{1}{2}\times 4\times(89.90-22.67)$, at $z_2 \Rightarrow \frac{4}{3}$

$\Rightarrow 134.46$ $\Rightarrow 1.33$

$Pa_3 \Rightarrow 22.67\times4$, at $z_3 \Rightarrow 2$

$\Rightarrow 90.68$ ✓

$$\bar{z}\ (\text{Point of Application}) = \frac{Pa_1 z_1 + Pa_2 z_2 + Pa_3 z_3}{Pa_1 + Pa_2 + Pa_3}$$

$$\Rightarrow \frac{45.34\times5.33 + 134.46\times1.33 + 90.68\times2}{45.34 + 134.46 + 90.68}$$

$\Rightarrow 2.2228$ m (from base)

Q.2 (c) (i) What do you understand by permeability of soil? Explain the factors affecting permeability.

(ii) Explain the laboratory methods of determination of coefficient of permeability in coarse and fine grained soils with neat sketches. Derive the expression for coefficient of permeability in the both the cases.

[6 + 14 = 20 marks]

Sol^n

(i) Permeability of Soil

	Permeability
Gravel -	< 1 cm/sec
Sand	$1 - 10^{-3}$ cm/sec
Silt	$10^{-3} - 10^{-7}$ cm/sec
Clay	$< 10^{-7}$ cm/sec

Permeability is defined as the Rate of water seep through the soil strata.

According to the Darcy's law

Velocity of flow through the soil $\boxed{(v) = Ki}$

$\boxed{K \Rightarrow \text{coeff. of permeability}}$

$i \Rightarrow$ head loss per unit length

but the actual velocity of flow through the soil is different as Area of voids through which seepage is occuring is diff. Hence

velocity of water through voids $\boxed{V_p = K_p i}$

$\boxed{K_p \Rightarrow \text{coeff. of percolation}}$

$K_p = \frac{K}{\eta}$ $\quad \because \eta = $ Porosity.

(A) Permeability is higher for coarse grained soil & lesser for fine grained soil.

factors Affecting permeability

(1) Void ratio

⇒ $K \propto \frac{e^3}{1+e}$

Coeff. of permeability largly depend upon dia or size of ~~partical~~ (governing factor) other than the dia or size of particle, void ratio also affects the coeff. of permeability as the relation above written.

(2) fluid properties

⇒ Coeff of Permeability also depend upon the fluid flowing through it as shown in below Relation

$$K \propto \left(\frac{\gamma}{\mu}\right)_{fluid}.$$

6

γ ⇒ unit wt of fluid flowing through soil

μ ⇒ dynamic viscosity of fluid.

(3) Dia of particls

⇒ governing factor of coeff. of permeability is dia or size of particle

$$K \propto D_{10}^2$$

⇒ It is varies directional to the square of the dia of particles.

(4) Water content or Saturation.

→ $K \propto$ water content.

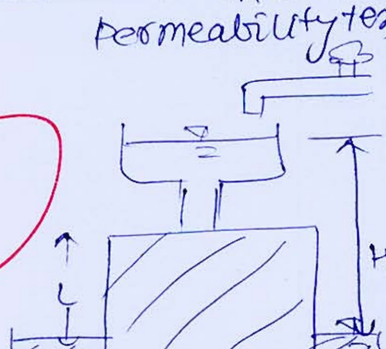
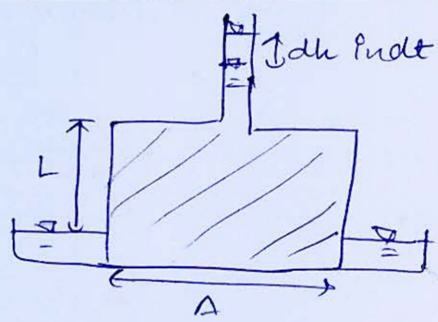
Coeff of Permeability increases as their's saturation or may say water content is increasing.

(5) Impurities or air content

→ $K \propto \dfrac{1}{\text{Impurities or air content}}$

Coeff. of permeability decreases on increasing the Impurities & air content.

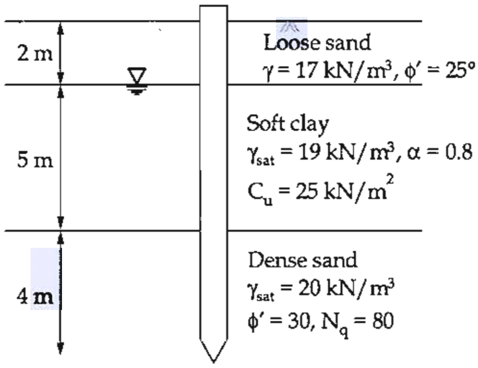
(ii)

Coarse grained (constant ~~head~~ head permeability test)	Fine grained (falling head Permeability test)
	
maintaining constant head	volume decrease in dh $\Rightarrow -a\,dh$ (a is the area of tube)
$Q = K i A$	Q(discharge) in dt time $\Rightarrow -a\dfrac{dh}{dt}$
$Q \Rightarrow K \times \dfrac{H}{L} \times A$	$K i A = -a\dfrac{dh}{dt}$
$K \Rightarrow \dfrac{QL}{AH}$	$K\dfrac{h}{L}A = -a\dfrac{dh}{dt}$
or $\boxed{K \Rightarrow \dfrac{V}{A i t}}$	$\displaystyle\int_0^t \frac{KA\,dt}{aL} \Rightarrow \int_{h_1}^{h_2} \frac{-dh}{h}$
	$\dfrac{KA}{aL}(t) \Rightarrow \log_e \dfrac{h_1}{h_2}$
	$\boxed{K \Rightarrow 2.303\,\dfrac{aL}{At}\log_{10}\dfrac{h_1}{h_2}}$

10

also explain theoretical portion of both the tests

Q.3 (a) Determine the allowable load carrying capacity of a 50 cm diameter driven concrete pile as shown in figure.



(Assume, FOS = 2.5)

Given: Values of k and δ as in table below.

Pile material	δ	Values of k	
		Loose sand	Dense sand
Steel	20	0.5	1.0
Concrete	0.75ϕ	1.0	2.0
Timber	0.67ϕ	1.5	4.0

[20 marks]

Q.3 (b) (i) With neat sketches, briefly explain the two fundamental crystal sheets of the clay minerals, viz. the tetrahedral and the octahedral sheet.

(ii) Describe different types of structure of clay mineral formed on the basis of arrangements of silica sheet and the octahedral sheet. **[8 + 12 = 20 marks]**

Q.3 (c) (i) The following test results were obtained on a soil sample:

Percentage passing through 4.75 mm IS sieve = 96%

Percentage passing through 75 μ IS sieve = 10%

D_{60} = 0.23 mm, D_{30} = 0.20 mm, D_{10} = 0.17 mm

Liquid limit = 27%; Plasticity limit = 18%

Classify the soil by IS classification.

(ii) A granular soil deposit is 6 m deep and lies over an impermeable layer. The ground water table is 3 m below the ground surface. The deposit has a zone of capillary rise of 1 m with a saturation of 60%. Plot the variation of total stress, pore water pressure and effective stress with the depth of deposit.

Given $e = 0.5$ and $G_s = 2.65$.

[8 + 12 = 20 marks]

Q.4 (a) **(i)** What are the assumptions involved in Boussinesq's and Westergaard's theory of stress distribution. Explain, which of the two theories is better suited for natural soil deposits.

(ii) A loading of 60 kN/m^2 is acting on an annular foundation of width 5 m and inside diameter of 8 m. Find the vertical stress intensity at a depth of 10 m below the centre of the foundation.

[10 + 10 = 20 marks]

solⁿ:

(i) Boussinesq's Assumptions

- Non-stratified Soil Stratum
- Isotropic, semi-infinite & Homogeneous Stratum.
- Boussinesq theory gives lesser value than westergaard Eqⁿ but it is considered because it gives safer value.

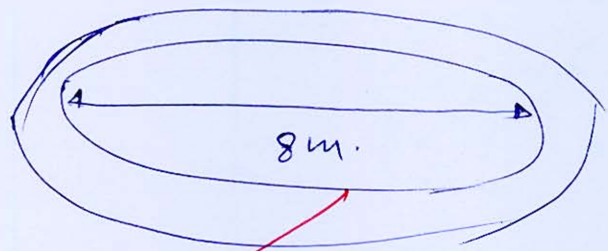
6

Westergaard's Eq^n

↳ for Stratified soil stratum

↳ Non-Isotropic, semi-infinite & Homo-geneous stratum.

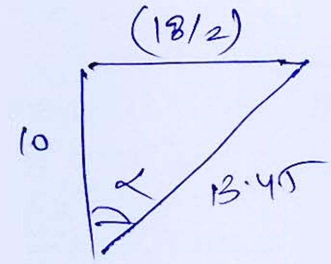
(ii)



$D_i \Rightarrow 8m$ (Inside Dia)

$D_o \Rightarrow 8+5+5 \Rightarrow 18$ (outer Dia)

Vertical stress intensity at 10m below by the outer Ring.



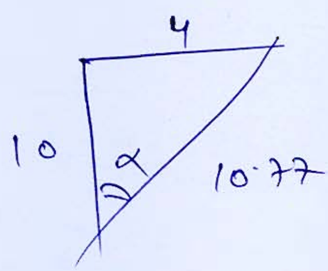
$\sigma_1 \Rightarrow q(1-\cos^3\alpha)$

$\sigma_1 \Rightarrow 60\left[1-\left(\frac{10}{13.45}\right)^3\right]$

$\cos\alpha \Rightarrow \frac{10}{13.45}$

$\sigma_1 \Rightarrow 35.34$

vertical stress due to inner ring



$\sigma_2 \Rightarrow q(1-\cos^3\alpha)$

10

$\sigma_2 \Rightarrow 60\left(1-\left(\frac{10}{10.77}\right)^3\right)$

$\sigma_2 \Rightarrow 11.97$

(A) ~~Net~~ Stress at 10m below the Centre of the foundation $= \sigma_1 - \sigma_2$

$\Rightarrow 35.34 - 11.97 = \boxed{23.37 \text{ kN/m}^2}$

Q.4 (b) A footing 2.5 m square, rests on a soft clay soil with its base at a depth of 2 m from ground surface. The stratum is 4 m thick and is underlain by a firm sand stratum. The clay soil has the following properties:

$w_L = 30\%$, $w_n = 40\%$, $G_s = 2.65$, $\phi_u = 0$, $C_u = 0.5\ \text{kg/cm}^2$.

It is known that the clay stratum is normally consolidated. Using Skempton's equation, determine the net safe bearing capacity of the soil (in t/m^2). Compute the settlement that would result if this load intensity were allowed to act on the footing. Natural water table is at the ground surface. Assume the load spread of 2 V : 1 H and factor of safety of 3.

[20 marks]

Solⁿ

$B = 2.5 m$, $D_f \Rightarrow 2 m$

(1) Net Safe Bearing Capacity

$q_{nu} \Rightarrow C N_c$

$N_c \Rightarrow 6\left(1+0.2\frac{D_f}{B}\right)$

$\Rightarrow 6\left(1+0.2\times\frac{2}{2.5}\right)$

$\Rightarrow 6.96$

$(6 < N_c < 9$, okay$)$

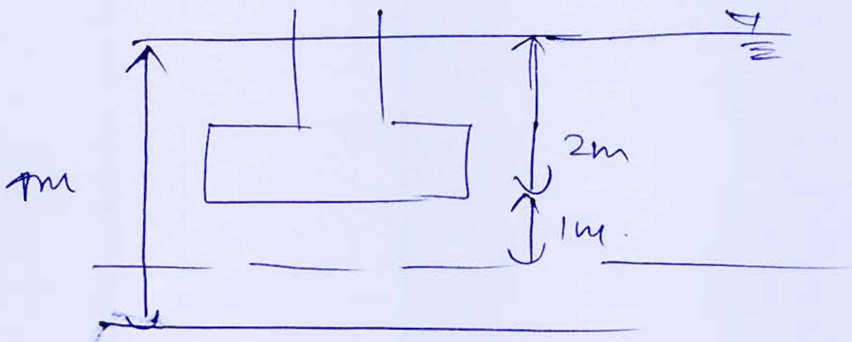
$$q_{nu} \Rightarrow 0.5 \frac{kg}{cm^2} \times 6.96$$

$$q_{nu} \Rightarrow \frac{0.5 \times 10^{-3}}{(10^{-4})\ m^2} \times 6.96 \text{ tonnes}$$

$$\boxed{q_{nu} \Rightarrow 34.8 \frac{\text{tonnes}}{m^2}} \Rightarrow \boxed{q_{ns} \Rightarrow 11.6 \frac{\text{tonne}}{m^2}}$$

for FOS = 3

(B) Settlement



Step-1 $H_0 = 2m$

Step-2 $\bar{\sigma}_0 \Rightarrow 3\gamma' \Rightarrow 3\gamma_{sat} - 3\gamma_w$

$$\left\{ \gamma_{sat} \Rightarrow \left(\frac{G+e}{1+e}\right)\gamma_w \Rightarrow 9.81\left(\frac{2.65 + .40 \times 2.65}{1+.40 \times 2.65}\right) \right.$$

$e = wG$, $S=1$

$$\gamma_{sat} \Rightarrow 17.67 \ KN/m^2$$

$\bar{\sigma}_0 \Rightarrow 3 \times 17.67 - 3 \times 9.81$

$\Rightarrow 23.58$

Step-3 $$\Delta\bar{\sigma} \Rightarrow \frac{q_{ns} \times B^2}{(B+2nz)^2} \quad \left\{ \begin{matrix} z \Rightarrow 1m \\ n \Rightarrow 0.5 \end{matrix} \right\}$$

$$\Delta\bar{\sigma} \Rightarrow \frac{11.6 \times 10^3 \times 9.81 \times 10^{-3} \times 2.5^2}{(2.5 + 2 \times 0.5 \times 1)^2}$$

$$\Delta\bar{\sigma} = 58.059 \ KN/m^2$$

Step-4

$$\Delta H = \frac{C_c H_0}{1+e_0} \log\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$

$$C_c \Rightarrow 0.009(w_L - 10)$$

$$\Rightarrow 0.009(30-10) \Rightarrow 0.18$$

$$e_0 \Rightarrow \frac{wG}{S} \Rightarrow \frac{0.40 \times 2.65}{1}$$

$$\Rightarrow 1.06$$

$$\Delta H \Rightarrow \frac{0.18 \times 2}{2.06} \log\left(\frac{23.58 + 58.059}{23.58}\right)$$

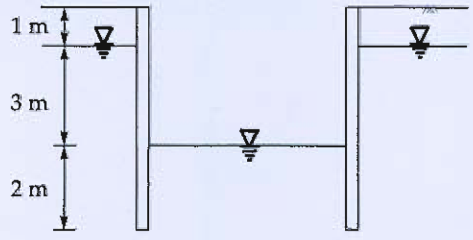
$$\Delta H = 0.0935 \text{ m}$$

$$\boxed{\Delta H \Rightarrow 93.5 \text{ mm}}$$

20

Q.4 (c) **(i)** What do you mean by consistency of clay? Explain 'ATTERBERG LIMITS' in detail.

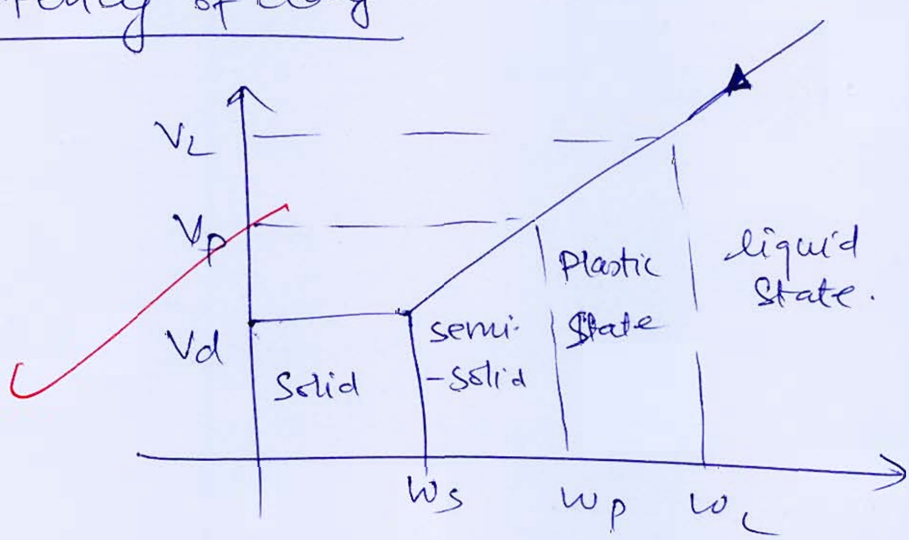
(ii) A trench is excavated in fine sand for a building, up to depth of 4 m. The excavation was carried out by providing the necessary side supports for pumping water. The water levels at the sides and bottom of the trench are as given in figure. Examine wheather the bottom of the trench is subjected to a quick sand condition if $G = 2.64$ and $e = 0.7$. If so, suggest the remedies.



[10 + 10 = 20 marks]

Sol^{n}:-

(i) <u>consistency of clay</u>



→ up to the shrinkage limit (ws) the volume of the soil is ~~remain~~ same & no change in void ratio, porosity etc

→ At ws (shrinkage limit), soil gains saturated condition (s = 1) And soil is in solid state.

→ on further increasing the water content the soil becomes super saturated ($s \neq 1$) and when the ~~liq~~ water content is such that the soil can be rolled to a thread of 3 cm then this moisture

Content is called as the Plastic limit

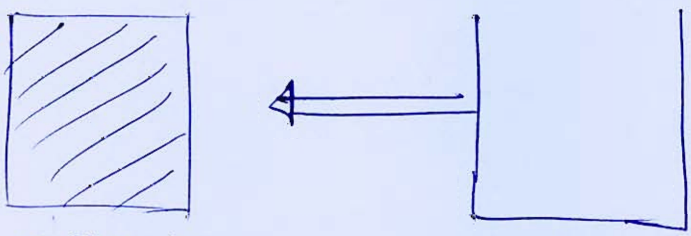
→ On further increasing the water content, the soil will starts to flow with a negligible shear strength of 2.7 kN/m² this moisture content is called liquid limit.

w_s (shrinkage limit), w_p (Plastic limit), w_L (liquid limit) are called the Atterberg limit.

$$\frac{dy}{dx} \Rightarrow \frac{w_L - w_p}{V_L - V_p} = \frac{w_p - w_s}{V_p - V_d} = \frac{w_L - w_s}{V_L - V_d}$$

(A) w_s (shrinkage limit)

8



Soil in dry state, Md, volume = Vd.

Moist soil have volume = V_1 and water content w_1

$$\boxed{w_s \Rightarrow w_1 - \left(\frac{V_1 - V_d}{M_d}\right)\rho_w}$$

(A) w_L

↳ found with the help of casagrande's Apparatus.

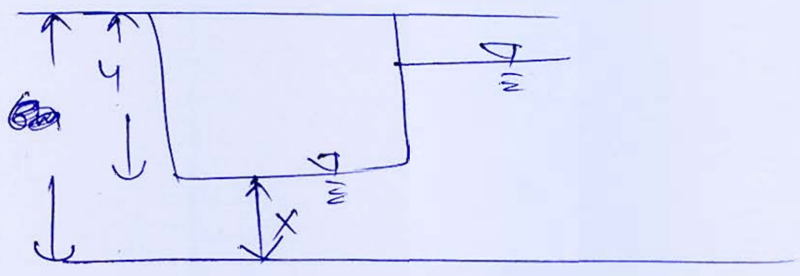
the water content with respect to 25 No. of blows are found out. on the Casagrande's Apprratus.

(iii) $\gamma_{sat} \Rightarrow \left(\frac{G+e}{1+e}\right)\gamma_w \Rightarrow \left(\frac{2.64+0.7}{1.7}\right)\times 9.81$

$\Rightarrow 19.27 \ KN/m^2$

$h_w \Rightarrow 5m.$

$H - x \Rightarrow 4$



Seepage pr = Seepage wt.

$\cancel{x}\frac{(h_w - x)\gamma_w}{\cancel{x}} = x\gamma'$

$h_w\gamma_w = x\gamma_{sat}$

$x = \frac{h_w\gamma_w}{\gamma_{sat}} = \frac{5\times 9.81}{19.27}$

8

$\boxed{x = 2.5454\ m}$

$FOS \Rightarrow \frac{x\gamma'}{(h_w - x)\gamma_w} \Rightarrow \frac{2.5454\times(19.27-9.81)}{(5-2.5454)\times 9.81}$

$FOS \Rightarrow 0.99$

Not safe.

Remedies
↳ lower the water table.

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Section B : Environmental Engineering

Q.5 (a) The population of a town as per the census records are given below for the years 1961 to 2021. Assume that the scheme of water supply will commence to function from 2026.

Year	Population
1961	42,560
1971	47,820
1981	63,500
1991	86,452
2001	1,11,230
2011	1,39,886
2021	1,82,800

Estimate the population of town after 30 years from the commencement of water supply scheme using geometric and incremental increase method.

[12 marks]

Sol^{n}

Water supply will commence from

2026 + 30 ⇒ 2056

n from 2021 ⇒ 3.5 decades.

Year	Population	Δx	$r = \frac{\Delta x}{P_1} \times 100$	$\Delta y = x_2 - x_1$
1961	42560			
		5260	$\frac{5260}{42560}$ ⇒ 12.35%	
1971	47820			10420
		15680	32.78%	
1981	63,500			7272
		22952	36.14%	
1991	86,452			1826
		24778	28.66%	
2001	1,11,230			3878
		28656	25.76%	
2011	1,39,886			14258
		42914	30.67%	
2021	1,82,800			
		Σx ⇒ 23373.3	$\bar{r}$ ⇒ 26.30%	$\bar{y}$ ⇒ 7530.8

a) Geometric method

$P_{2056} \Rightarrow P_0\left(1 + \frac{r}{100}\right)^n$

$\Rightarrow$ ~~182800 + 3.5×~~

$182800\left(1+\frac{26.30}{100}\right)^{3.5}$

$\Rightarrow 413892.8446$

$\boxed{P_{2056} \Rightarrow 413893}$

b) Incremental Increase Mtd

$P_n \Rightarrow P_0 + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$

$P_{2056} \Rightarrow 182800 + 3.5 \times 23373.3 + \frac{3.5 \times 4.5}{2} \times 7530.8$

$\boxed{P_{2056} \Rightarrow 32391.16}$

12

Q.5 (b) Derive governing equation for settling of discrete particles in laminar flow.

[12 marks]

$V_s = \frac{4}{3}\sqrt{\frac{gd(G-1)}{C_D}}$ (or all flows)

derive

In laminar flow

$C_D = \frac{24}{Re}$

d = dia of particles

g = Acc^n due to gravity.

G = specific gravity.

6

$V_s = \frac{4}{3}\sqrt{\frac{gd(G-1)}{C_D}}$

C_D = coeff of drag

$C_D = \frac{24}{Re}$ for laminar flow

$C_D = \frac{24}{Re} + \frac{Re}{\sqrt{3}} + 0.34$ for transition flow

$\Rightarrow V_s = \frac{4}{3}\sqrt{\frac{gd(G-1)}{C_D}}$

$V_s = \frac{4}{3}\sqrt{\frac{gd(G-1)}{24/Re}}$

$V_s = \frac{4}{3}\sqrt{\frac{gd(G-1)}{24 / \frac{V_s d}{\nu}}}$

$\frac{3^2}{4^2} V_s^2 = \frac{gd(G-1)}{24 / \frac{V_s \times d}{\nu}}$

Do not write in this margin

$$\boxed{V_s = \frac{d^2 g (G-1)}{18 \nu}}$$

↳ for laminar flow

$$\boxed{\begin{gathered} d < 0.1\,mm \\ Re < 1 \end{gathered}}$$

Q.5 (c) Explain the following control devices for particles:
(i) Cyclone collectors. (ii) Electrostatic precipitators.
(iii) Fabric filters

[12 marks]

→ (ii) Electrostic Precipitator

4

$$\eta = 100\left(1 - e^{-\frac{\omega}{AQ}}\right)$$

Theory ??

ω = migration velocity

A = Area of plates

Q = Discharge ~~rate~~

↳ for particulate matter.

(i) Cyclone collectors

↳ for small particles have smaller efficiency ↳ for particulate Matter

(iii) fabric filter
↳ Bag are used to ~~collect~~ collect
large dia. particle,
↳ eff. is less.

Q.5 (d) Design a septic tank for a colony of 250 people. The colony is supplied water at a rate of 135 litres/person/day. Assume a detention period of 24 hours and 80% of water becomes waste water. The tank is cleaned once in a year. The rate of deposition of sludge is 42 litres/person/year. Depth of tank is to be kept as 2.0 m. Provide a free board of 0.3 m. Length to breadth ratio may be kept as 3.5 : 1.

[12 marks]

Solⁿ:

Volume of ~~sludge~~ Sewage

$V_1 \Rightarrow 0.80 \times 135 \times 250 \times 10^{-3} \ \frac{m^3}{Day}$

$\Rightarrow 27 \ \frac{m^3}{Day}$.

Volume of sludge

$V_2 \Rightarrow 42 \times 250 \times 10^{-3} \ \frac{m^3}{year}$

$\Rightarrow 10.5 \ \frac{m^3}{year}$

Total Volume of septic tank.

$\Rightarrow V_1 \times D_t + V_2$ (Rate of sludge Accumulation) $\times$ Desludging Interval)

$$\Rightarrow 27\,\frac{m^3}{day} \times 1\,day + 10.5\,\frac{m^3}{year} \times 1\,year$$

$$\Rightarrow 37.5\,m^3$$

$$\frac{L}{B} = \frac{3.5}{1} \quad \& \quad H = 2m$$

$$L = 3.5B$$

$$Volume = 37.5$$

$$LBH = 37.5$$

$$3.5B^2 \times 2 = 37.5$$

$$\boxed{B = 2.314\,m}$$

$$\boxed{L = 8.1\,m}$$

12

final dimension

$$\boxed{\begin{aligned} B &= 2.314\,m \\ L &= 8.1\,m \\ H &\Rightarrow 2 + 0.3 = 2.3\,m \end{aligned}}$$

$$\left\{ \begin{array}{ll} Min\ width = 0.75\,m & (okay) \\ \frac{L}{B} = 2-4 & (okay) \end{array} \right\}$$

Q.5 (e) The BOD_5 of waste water is 150 mg/lt at 20°C. The deoxygenation constant (base 10) is 0.1 per day. What would be $(BOD)_8$, if the test is performed at 15°C?

[12 marks]

5δ²⁰

(1) $(BOD)_5 = 150$ mg at 20°C

$(BOD)_5 = (BOD)_u (1 - 10^{-Kt})$

$150 = (BOD)_u (1 - 10^{-0.1 \times 5})$

$BOD_u = \cancel{129.31}$ 219.37 mg/l

(2) $K_{(15°C)} = K_{20} (\theta)^{T-20}$

$K_{15°C} = 0.1 \times (1.056)^{15-20}$

$= 0.076$

(3) $(BOD)_8 = (BOD)_u (1 - 10^{-Kt})$

$= \cancel{129.31}$ $219.37 (1 - 10^{-0.076 \times 8})$

$= 165.272$ mg/l.

12

Q.6 (a) Design a rapid sand filter unit with rate of filtration as 5000 lt/hr/m² for 4 million litres per day of supply with all its principal components.
[Assume 4% of filtered water is required for washing the filter with rate of washing as 60 cm rise/minute and 30 minutes is required for filter washing per day]

[20 marks]

ROF = 5000 l/hr/m²

Q = 4 MLD

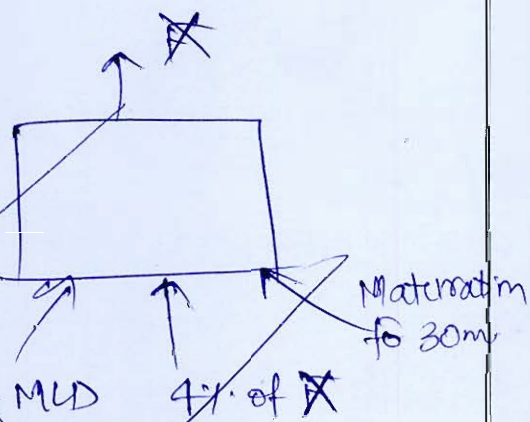
$X = 4\times10^3 \frac{m^3}{Day} + 0.04X$

$+ (ROF) A \times \frac{30}{60} \times 4$

(Assume Area of each unit = 80 m²)

No. of units = 4

$X = \cancel{4}\times10^3 \frac{m^3}{day} + 0.04X + \frac{5000\times10^{-3}\times 24 \times 50 \times 4}{2} \frac{m^3}{day}$



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$X = 4 \times 10^3 + 0.04X + \frac{5000 \times 10^{-3} \times 24 \times 50 \times 4}{2}$

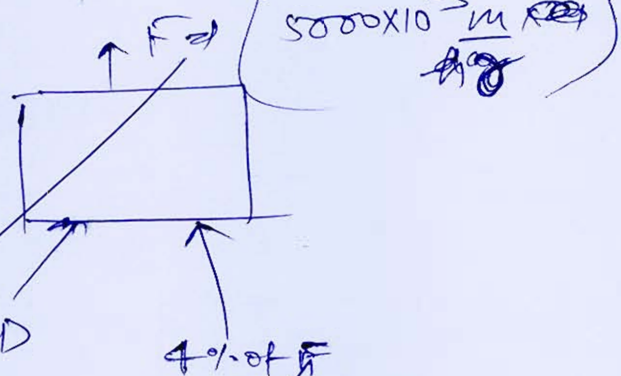
(filtered water) $X = 16{,}666.67 \ \frac{m^3}{Day}$

$X = 16.67$ MLD

or 16.67 MLD

(A) check.

$v = 1.22\sqrt{52}$



Assume
Area of Each unit = 50 m²
n = 4

(A) $F = 4 \times 10^3 \ \frac{m^3}{Day} + (0.04 \times F)$ → ①

(A) Volume of filtered water = $(5000 \times 10^{-3} \times A \times 23.5) \ \frac{m^3}{8}$ → ②

(A)

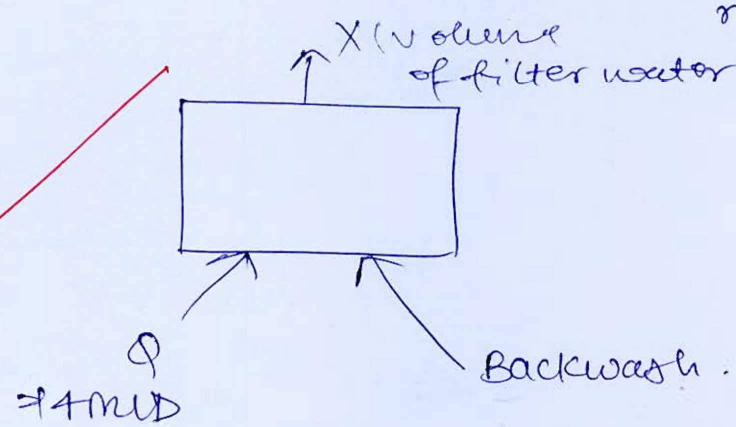
PTO

a) ROF ⇒ 5000 l/hr/m²

Q = 4 MLD

Backwashing ⇒ 4% of filtered water for 30 minutes.

ROB ⇒ 60 cm/minute.



X ⇒ (ROF) × Area × time.

$\Rightarrow 5000 \times 10^{-3} \frac{m}{hr} \times A \times 23.5\,hr = 117.5 A\, m^3$

Backwash ⇒ 0.04X ⇒ $0.04 \times 117.5 A\, m^3$

⇒ $4.7 A\, m^3$

4

X ⇒ Q + 0.04 X

$X \Rightarrow 4 \times 10^3 \frac{m^3}{day} + 0.04X$

$\boxed{X \Rightarrow 4166.67\ m^3}$

Volume of filtered water

Assume Area of Each unit ⇒ 100 m²

& H ⇒ 7 m

~~Each unit ⇒ ... ⇒ 100 m²~~

~~Assume Area of ... H ⇒ 2m.~~

~~Assume, ...~~

~~Area of~~

then no. of units ⇒ $\frac{4166.67}{100 \times 7} \Rightarrow 5.95 \simeq 6$

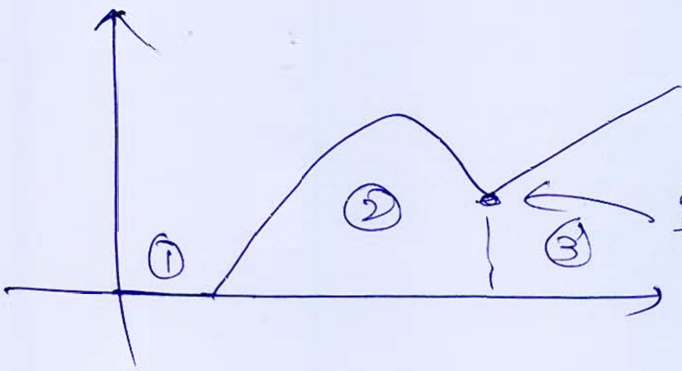
1 standy ⇒ total units ⇒ 7.

Q.6 (b) (i) Explain breakpoint chlorination along with its advantages.

(ii) What are the tests done for chlorine residuals? Explain.

[8 + 12 marks]

Soln:- i)



Step ① Reduction of Reducing agent like Fe^{3+}, Mn^{2+} with the help of Cl_2, NH_3

Step ② Killing of Micro-organism along with the formation of chloramines.

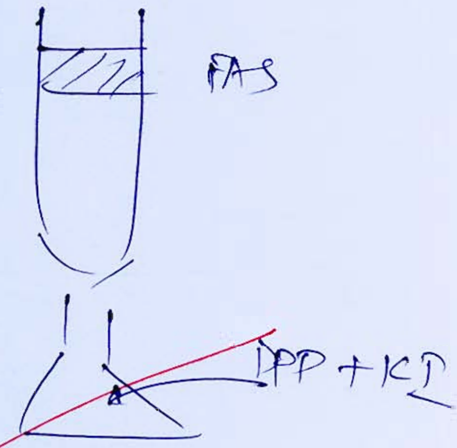
Step-3 Reducing of chloro-organics & leave a Residual chlorine Amount called Breakpoint chlorined.

6

- If NH_3 is not used then, the amount of residual free chlorine ≯ 0.2 mg/L (because it will make water bitter)
- So chloroamines are used as Residuals
- At Breakpoint chlorined all Microorganism are killed & there will be a Residual also

(ii) test for Cl_2

a) DPD test



→ DPD with Potassium Iodide (KI) is mixed in water then treated with ferrous Ammonium sulphate.

→ the gm. eq. of FAS consumed
→ the total chlorine Residual gm. eq. in water.

b) DPD test for free chlorine

→ DPD is mixed in water ~~then~~ then treated with FAS

→ the gm. eq of FAS consumed.
→ the free chlorine - Residual gm. eq. in water.

(c) Amphoteric
→ carcinogenic hence not used
But ~~it~~ seperately find free Residual residual & total chlorine

(C) orthotoulidene
↳ can't distinguish b/w ~~total~~ chlorine
Residual & free chlorine

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Q.6 (c) A circular sanitary sewer is designed to carry the maximum flow of sewage while flowing 70% full at a velocity of 0.9 m/sec. If the ratio of $\frac{\text{Maximum}}{\text{Average}}$ and $\frac{\text{Average}}{\text{Minimum}}$ flow are 3 and 2.5 respectively, find out:

(i) The proportionate depth of flow.

(ii) The velocities of flow generated at the time of average flow and minimum flow.

(The variation of Manning's 'n' with depth may be neglected).

[20 marks]

Soln

$Q \Rightarrow AV$

Q.7 (a) **(i)** Determine the size of a high rate trickling filter for the following data:

1. Sewage flow = 4.5 MLD
2. Recirculation ratio = 1.5
3. BOD of raw sewage = 250 mg/lt
4. BOD removal in primary tank = 30%
5. Final effluent BOD desired = 30 mg/lt.
6. Depth of filter = 1.5 m

(ii) What are different zones of pollution in a river stream?

[15 + 5 = 20 marks]

Q.7 (b) (i) Design a digestion tank of depth 6 m for the primary sludge with the help of following data:

1. Average flow = 20 MLD.
2. Total suspended solids in raw sewage = 300 mg/lt.
3. Moisture content of digested sludge = 85%.
4. Digestion period = 30 days.
5. 65% of solids are removed in primary settling tank.
6. Moisture content of fresh sludge = 95%
7. Moisture content of digested sludge = 85%
8. Specific gravity of wet sludge = 1.02

Assume any other suitable data if required.

(ii) Explain productivity of lake. Also explain the types of lakes based on increasing level of its productivity.

[12 + 8 = 20 marks]

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Q.7 (c) A town with a population of 30,000 requires a sewage treatment plant to handle industrial as well as domestic wastewaters of the town. A sanitary survey revealed the following: Dairy wastes of 3 million litres per day with BOD of 1100 mg/lt and sugar mill waste of 2.4 million litres per day with BOD of 1500 mg/lt are produced. In addition, domestic sewage is produced at the rate of 240 litre per capita per day. The per capita BOD of domestic sewage being 72 gm/day. An overall expansion factor of 10% to be provided. The sewage effluents are to be discharged into a river stream with a minimum dry weather flow of 4500 lt/sec. and a saturation dissolved oxygen content of 9 mg/litre in the stream. Determine the degree of treatment required to be given to the sewage. Assume coefficient of deoxygenation and coefficient of deoxygenation as 0.1 and 0.3 day^{-1} (base 10) respectively. The dissolved oxygen content is not to fall below 4 mg/lt.

[20 marks]

Q.8 (a) (i) Explain different types of plumes along with their neat sketches.

(ii) Determine the effective height of a stack with the following given data:

(a) physical stack is 180 m tall with 0.95 m inside diameter.

(b) wind velocity is 2.75 m/sec.

(c) barometric pressure is 1000 millibars.

(d) stack gas velocity is 11.12 m/sec.

(e) stack gas temperature is 160°C.

[15 + 5 = 20 marks]

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Q.8 (b) An activated-sludge system is to be used for secondary treatment of 10000 m^3/d of municipal wastewater. After primary classification, the BOD is 150 mg/lt and it is desired to have not more than 5 mg/lt of soluble BOD in the effluent. A completely mixed reactor is to be used, and pilot-plant analysis has established the following kinetic values: y = 0.5 kg/kg, $k_d = 0.05 d^{-1}$. Assuming MLSS concentration of 3000 mg/lt and an underflow concentration of 10000 mg/lt from the secondary clarifier, determine:

1. The volume of the reactor.
2. The mass and volume of solids that must be wasted each day.
3. The recycle ratio.

[Assume sludge age = 10 days]

[20 marks]

Q.8 (c) (i) Convert 150 mg/m^3 of SO_2 concentration at 20°C into ppm.

(ii) A 0.6 m well is constructed in an unconfined aquifer of thickness 20 m. Assume that aquifer to be composed of sand with permeability of 50 m/day and storage coefficient $S_c = 0.22$. The original piezometric surface is 10 m below ground surface. After pumping the well for 1 day, the drawdown in the observation well 25 m away is 2.5 m. Calculate the pumping rate that caused this drawdown. Maintaining this pumping rate, what will be the drawdown in the observation well after 1 year?

[10 + 10 = 20 marks]

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■■■■

Space for Rough Work

Space for Rough Work